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Nutrient exchange between surface water and shallow groundwater and degradation pathways of nitrogen species in the North China Plain

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While there is worldwide growing demand for agricultural food production, pressures on water resources increase. This is especially obvious in the North China Plain, where about one third of the annual national harvest of staple foods such as wheat and maize are produced - mainly via irrigated agriculture. In this region, high competing water use between different sectors has led to declining groundwater tables and substantial water pollution in rivers, lakes, and even aquifers. In order to lay the basis for suitable water management and protection measures, it is therefore important to understand how groundwaters and surface waters affect each other in terms of pollutant exchange.

Here, the results of a one-year study on water flow interactions and chemical influences between groundwater and river water at a winter wheat – summer maize double cropping system site, Hebei Province, China, are presented. The study entailed eleven field campaigns during which samples for nitrogen species, major and minor ion composition, and stable isotopes were taken from a river passing directly adjacent to the wheat-maize field, the hyporheic zone below the river, soil water at different depths (0.4, 0.8, and 1.2 m), and groundwater at 2.1 m depth and different distances (1-41 m) from the river bank.

A high degree of interconnectedness between surface water and groundwater with flow from the river into the shallow aquifer was identified. Major inflowing pollutants into the aquifer were nitrogen via vertical transport from the land surface (concentrations in the upper suction cup from 63.0 to 134.3 mg/L NO3-N) and ammonia and nitrate via horizontal transport from the surface water (concentrations between 9.0 and 29.8 mg/L NH4-N and n.d. to 6.8 mg/l NO3-N). Despite these high inputs, both nitrogen species were only detected at much lower concentration averaging at 1.8 mg/L NO3-N and 3.6 mg/L NH4-N in groundwater samples at 2.1 m depth, indicating a high capacity of the system to remove excess reactive nitrogen. Suggested removal mechanisms supported by modelling include nitrification/denitrification processes, cation exchange, or anaerobic ammonium oxidation (anammox). Despite the current capacity of the soil-groundwater system to cope with incoming pollutants, the intense agricultural use, combined with the large amounts of instreaming ammonium pollution, may pose a future threat to the quality of the shallow aquifer and to the soil in the studied system. Monitoring of the river and groundwater quality and measures for quality improvement of the surface water is therefore recommended.